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STUDIES FOR STUDENTS

THE CRITERIA REQUISITE FOR THE REFERENCE OF RELICS TO A GLACIAL AGE.[1]

INTRODUCTION.

THE criteria herein discussed are given shape with special reference to human relics because these possess pre-eminent interest, but they are equally applicable to all relics, whether they are those of man, of animals, or of plants. The criteria are also defined with special reference to America, though they are equally applicable to the Old World. This is not by any means to say that the facts are the same on the two continents.

The theoretical grounds for assuming the existence of man *somewhere* on the globe in preglacial times are very strong. In Europe the evidences of man's presence during some of the interglacial periods appear to be substantial. So far as America is concerned, the question is purely one of fact to be determined strictly by scientific evidence. There seems to me little or no legitimate ground for a predisposition to accept or to decline to accept a glacial or preglacial antiquity for man in America. The existence of the race upon the eastern continent in glacial times does not carry any special presumption of its existence upon the western continent at that time. The belief that man originated upon the eastern continent rather than upon the western has something of strength in biological considerations, and is supported by the preponderance of existing geological evidence. If man originated in the Old World, the time when he migrated to the New is an open question until it is closed by thoroughly sound evidence, precisely as it is in the case of the migration of any of the mammals which originated upon the eastern continent and is now a denizen of the western. If it is a more important matter to us, it is the more important that its evidence be sound. The notion that the life-history of one grand division is to be "brought into accord" with that of another is a perilous guide. In certain general aspects, the life-history of the several subdivisions may indeed have points of accord, but in its special phases divergence is quite as much the rule as concordance. In any given case, the probabilities are that a given form originated in one grand division rather than in all, and that more or less time elapsed before it migrated to distant regions. There is therefore no presumption that all the early stages of evolution will be found on all the continents.

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[1] Read in abstract before Section E, A. A. A. S., Washington Meeting, January, 2, 1901.

Nor do I see any good scientific reason to desire one result rather than another. I see no scientific grounds for a predisposition to match European antiquity by American antiquity, or the European stages of evolution by American stages of evolution. It is quite as much in the interest of ethnological science, so far as I can see, to limit the duration of the human species on the western continent as it is to extend it. Given three or four great divisions of the earth's surface in which a species may develop in measurable independence, probably as much, and perhaps more, can be learned from the introduction of the species into these several divisions at different and rather widely separated intervals, as can be learned by its introduction into all of them simultaneously, or in close succession. Evolution through periods of different lengths in the different divisions would probably show at least as much, if not more, of the rate and nature of development as would evolution for equal periods in all the divisions. We shall probably learn quite as much of the great lessons of human evolution if it shall be shown that the American races have developed since the glacial period, so far as they are endogenous, as if it shall be shown that the period reaches back to one or another of the interglacial epochs or to the preglacial period. In any case, to the ideal scientist, it is purely a question of fact to be settled by demonstrative evidence. Our concern here is what constitutes demonstrative evidence.

Evidence to be sought in the glacial formations themselves.— Grounds for assigning man to a glacial period are to be sought primarily in the glacial formations themselves. This is the principle we recognize in the assignment of a pebble or a bowlder, and it should hold good for human relics. A few years ago two of our most experienced glacialists and three younger associates reconnoitered seven states, and then held their conclusions in abeyance for several years, because they were not fully convinced that certain crystalline pebbles in certain gravels outside the true glacial formations were or were not truly glacial in origin. Had these pebbles been found in glacial deposits, their reference would not have caused a moment's hesitation. It is only applying to human relics the standards adopted by careful glacialists relative to pebbles, to insist that there is a profound distinction between the value of evidence from the direct glacial deposits and that from derivatives or secondary deposits.

I. EVIDENCE FROM PRIMARY GLACIAL DEPOSITS.

There are three good classes of cases connected with the primary glacial material:

1. The first of these is *imbedment in the till sheets or the moraines.* If the identification of the glacial deposits and of the relics be beyond question, relics found imbedded in the true glacial deposits constitute very strong evidence of contemporaneous or previous origin. There is some danger of error even here, however. Secondary deposits of till are liable to be confused with true original deposits. Slides, creep, and wash not infrequently bury recent material under what at first seems to be true bowlder clay. Many a time has the experienced and alert glacialist had occasion to use the most careful circumspection to avoid error in assigning wood, buried soils, and other fossils to a glacial or interglacial age, whose burial proved on close inspection to be secondary and utterly worthless for chronological purposes. There are also incidental intrusions by means of burrows, root holes, cracks, etc., which require elimination. If all these are excluded by expert observation *controlled by unrelaxing alertness and persistent caution,* evidence of a high order of value is theoretically derivable from the tills and the moraines.

I say "theoretically derivable," because no fully authenticated case of this kind has been presented as yet, so far as I know.

2. *Evidence from assorted drift included in till and moraines.*—Relics found in gravels or sands interbedded with true bowlder clays, when they are clearly of immediate glacial derivation, furnish nearly as good evidence as relics in the bowlder clays themselves, but their identification requires more circumspection.

3. *Evidence from kames and eskers.*—So also relics found in true kames or eskers may furnish good evidence if the sources of error are sufficiently avoided, but still more caution and alertness are required here.

Confirmatory evidence in these cases.—Glacial *striation*, besides being a source of evidence in itself, may afford supplementary evidence in these cases and may serve as a check on the sources of error previously noted. Unmistakable glacial striation may even make good what would otherwise be worthless evidence. For example, a well-striated bone found in secondary till might be accepted as good evidence of glacial antiquity, whereas if unstriated it would have to be excluded because the rearrangement or disturbance of the till would vitiate its trustworthiness. Striated stone implements must, however, be received with great caution, for, in the first place, stones that had long before been striated may be used in the construction of implements without obliterating all the striation, and, in the second place, use may give rise to grooves and scratches very like true glacial work. Erroneous identification of striæ are by no means uncommon in the history of glacial geology.

Combined evidences.—When well-authenticated striation is combined with imbedment in original glacial deposits, the evidence reaches its highest value. We have, however, so far as I know, no such cases as yet in America.

The culminative value of repetition.—The evidential value of *good* cases rises rapidly with their multiplication, for the doubts that might legitimately arise in a single case notwithstanding all precautions against error are effectually reduced by additional good cases. But, true as this is, no amount of multiplication of *bad cases* makes a *good* case. On the contrary, the multiplication of weak and false cases throws doubt on all and is a legitimate ground for rejecting all. The first step toward a firm ground of confidence is the sweeping away of all bad cases of the past and the effectual barring out of all new ones.

The interpretation of imbedded and striated relics. — Human relics found in the true glacial deposits, whether striated or not, do not necessarily tell whether man lived in the immediate presence of the ice or whether he had lived in the region *before* the ice invasion. (1) The relics may have been picked up from the preglacial surface by the ice as it pushed over the region, just as rock fragments and earthy matter were, or (2) they may have been dropped on the ice or at its border or on the moraines in the presence of the ice. If the relics are found to be associated with other organic remains that imply a warm climate, the former inference is favored; if the associated organic remains imply a cold climate, the latter inference is the more probable, but as all the relics are disturbed, the inference is not firm in either case. If human bones are found that show evidence of long weathering and subsequent striation, there is good ground for inferring the existence of man in the previous interglacial or preglacial period. The absence of weathering would not be equally good ground for the opposite inference, because certain kinds of burial exclude weathering.

A demonstration that man existed before a given glacial invasion would imply his existence during it in some part of the globe, and presumably in the grand division in which the relics were found, but a closer interpretation than this requires special evidence.

II. EVIDENCES FROM THE INTERGLACIAL DEPOSITS.

The interglacial deposits include those surface accumulations that were formed in the interval between the ice invasions of a given region. They are chiefly soils, muck, peat beds, and various wash products, including fluvial, lacustrine, and occasionally marine clays, silts, sands, and gravels. There were similar deposits outside the glaciated regions, but as these were not buried by later glacial deposits, they cannot generally be connected demonstrably with the glacial invasions, and are therefore not here included. The abandoned surface of a recently glaciated region furnishes excellent conditions for the burial and preservation of relics, for it usually presents an uneven surface which becomes dotted with ponds, swales, and ungraded valleys, so that erosion and deposition are the natural order of things. The basins furnish alluring grassy meadows and the ponds offer enticements to drink, while the bordering bogs and springy grounds lie in wait to mire the weak and unwary, and clayey inwash from the higher ground provides a preservative burial. Although the interglacial beds were subject to much disturbance and to removal during the succeeding ice invasion, they were preserved in a singularly large number of cases, and fossils, often in the most excellent state of preservation, are sometimes found in them. The delicate tissues of mosses are occasionally admirably retained.

The fossils of these beds have the further merit of definite fixity in time and localization. In this respect there is not the uncertainty of the previous class. The imbedded plants and animals lived subsequent to the deposition of the underlying drift and previous to that of the drift above.

But even here there is a source of some vagueness, though it is not radical. It is a not uncommon practice of glacial geologists to include among the interglacial formations gravels, sands, and clays, which overlie an earlier bowlder clay, even though it may be quite possible that these were formed in the last stages of the preceding glacial epoch, and are indeed nothing but the glacio-fluvial deposits of that epoch. Of course, this is not done by the discriminating glacialist where the case is determinate. But usually the case is not determinate, and then the interglacial epoch is given the benefit of the doubt. Any error in date arising from this source would be a conservative one, since the relics are, at the worst, only referred to a slightly later date than they are entitled to.

Sources of error connected with interglacial deposits.—The liability to error here is not very serious, if due circumspection is exercised.

There may be false identifications of the overlying and underlying glacial deposits and of the interglacial beds themselves, and there may be misinterpretations arising from that *bête noire* of the incautious glacialist, secondary displacement and rearrangement, but a duly trained and fairly skilful worker should avoid all these. These interglacial beds present by far the most promising field for the demonstration of the presence of man in America during the glacial period, if he really lived here then. No good case of relics from them, however, has yet been presented, so far as I know.

III. EVIDENCES FROM ASSORTED DRIFT LYING UPON OR OUTSIDE OF THE TRUE GLACIAL SERIES; RIVER DEPOSITS ESPECIALLY.

Nearly all the relics upon which the presence of man in America in the glacial period has been claimed are from deposits of this sort, and they hence deserve critical attention. For the greater part, these deposits are valley trains or frontal aprons of gravel, sand, and silt. There are three different classes of deposits of this kind that are remarkably similar in their general characters, but which must be positively distinguished from each other before any safe conclusions can be drawn. This is a work of grave difficulty, and in many cases I know of no way in which it can be successfully done. One of these classes is glacial, and the two others are postglacial. Before relics in these can be referred to the glacial period, it must be shown that the deposit bearing them belongs to the first class, and certainly does not belong to either of the other two.

1. The first class consists chiefly of gravel, sand, and silt borne out from the ice by the glacial waters and deposited along the glacial waterways. These are truly glacio-fluvial and strictly contemporaneous with the ice action. Contemporaneous burial in these means of course a glacial age.

2. The second class consists of sand, gravel, and silt of almost identical composition and structure formed by postglacial waters working on the drift surface and washing out from it the same class of material that the true glacial waters did and spreading it along the valleys in an almost identical way. More than this,

the deposits of this class are likely to be the uninterrupted successors of those of the previous class, and hence to overlie them conformably. There is therefore the most extreme difficulty in distinguishing the two under most conditions. In the case of outwash aprons and certain abandoned valleys, and in other particular cases closely adjacent to the ice edge, the discrimination can be made, but in most cases at a distance from the ice edge I know of no certain means by which it can be done. The postglacial modified drift should theoretically be somewhat more weathered than the true glacio-fluvial drift, but the amount of weathering which took place after the ice retreated and before the material was carried away and deposited would not in most cases be great, and what there was would largely be worn off in the transportation preliminary to the deposit of the material as modified drift. It is therefore an unavailable criterion.

3. The third class consists of the first and perhaps the second class reworked by the postglacial streams after they exchanged their *aggrading* habits to *degrading* ones. In this class the material is identical, or essentially identical, with that of the preceding classes, since it is the same material reworked, with some addition from the same general source, the drift of the region, and its structure is so closely similar that a careful glacialist would hardly venture to discriminate between them. The topography, especially the relations of the deposits to the terrace systems, where such exist, often aids in forming an impression of the probabilities, but in most cases it cannot go much beyond that.

Scour-and-fill.—The process which is most concerned in introducing the confusion of this third class is *scour-and-fill*, one of the most obvious processes in all geology, but one of the most neglected. It is a very familiar observation, if we but recall it, that every active stream has shallows and deeps, and that the differences in depth of water are very considerable. It is also certain that these are constantly changing, and that with the shifting of the course of the river they undergo complete obliteration and are replaced by flood plains. The whole bottom of the valley, so far as involved in the range of the river's meanders and other shiftings, is subject to this alternate erosion and filling. It is equally clear that any relics that may come within the river's action, except such as float, are liable to be buried to depths equal to the difference between the height of the flood plain and the depth of the deep holes in the bottom of the river. In the great rivers, this range not infrequently reaches 100 feet and more, and is very commonly three and fourscore feet. In many cases the scour reaches the rock bottom, and at such places the entire bottom deposit is undergoing reworking, and modern relics may be introduced into any of its depths. This phenomenon is most strikingly displayed in the Missouri river, where the engineers tell us that transient scour often reaches bed rock, and that the scooping out and filling up follow one another with almost seasonal frequency. So pronounced is this action that the impression has been given that the *whole bottom deposit is being shifted turn-by-turn down stream.* While this may be an overstrained deduction, it is supported by a great mass of very important facts, too much neglected. The erosion of the rock bottom of most streams is accomplished by such alternate shiftings of the loose bottom material. At any one time, this loose material covers most of the bottom of most degrading streams even, and the wear on the rock bottom is accomplished first here and then there by the shifting of the covering of loose material. In practically no streams at all, except perhaps mountain cascades, is the whole bottom exposed to erosion at the same time. In the drift-filled bottoms of the great branches of the Mississippi system, it is wholly within bounds to regard at least the upper 40 or 50 feet of the deposit over which the river meanders as subject to scour-and-fill and to entertain the suspicion that the deeper portions down to 100 feet or more may be similarly affected. To make out a good case for the antiquity of relics buried in such a deposit seems well-nigh impossible.

Scour-and-fill affects more or less every portion of a river deposit that has formed a part of the channel bottom at any time in its history. This action does not usually much affect the flood plains while they *remain such.* There are exceptions even here, and not very infrequent ones, but scour-and-fill is not normally an effective mode of action on the flood plains. And so a portion of a fluvial plain that has never been occupied by the river channel, but only by its upper floods, if indeed there be such a portion, would not be greatly open to the suspicion of having been reworked by scour-and-fill. But every part of the flood plain that is occupied at intervals by the stream's channel is subject to scour-and-fill, during the whole period of such periodic occupancy, and the contents of its deposits are subject to all the uncertainties of origin already pointed out.

Unequal effect on aggrading and degrading rivers.—Scour-and-fill affects both aggrading and degrading rivers, but it does not affect them equally. In aggrading rivers, especially those rapidly and declaredly building up their bottoms, as in the case of typical glacial streams, the river is usually broken up into a plexus of branches by the successive filling up of the channel bottoms and the diversion of the streams. Deep scour-and-fill is not a pronounced habit of such streams. Already overburdened with detritus, they have not that reserve capacity for taking up a new burden that clearer streams have, and their division into numerous weaker branches takes away the cumulative power which the combined and concentrated current of the clearer degrading streams possesses. The action reaches its greatest efficiency, it would seem, when the whole stream concentrates its full force in a limited portion of its channel, and when it is free to take on temporarily a large additional burden of detritus. The action is greatest at the turns of the streams where the arrested or diverted momentum of the current develops a powerful rotary movement of the water.

Breadth of action in the great streams of the glacial area.—Now this reworking of the fluvial deposits along the courses of the Missouri, the Mississippi, the Ohio, and many of the other large streams in the glacial area, occupies or has recently occupied nearly or quite all the space between the bounding bluffs. Here and there within protected recesses, or in other favored spots, there may be a few exceptions, but in most of these cases even it may be difficult to prove that the remnant deposits were not reworked in postglacial times, though somewhat remote ones. The only cases that can be held to be exempt from this suspicion are terraces that can be shown to be remnants of the original glacial flood plain and can be discriminated demonstrably from remnants of some one of the many flood plains that succeeded this original one in the history of the subsequent erosion of the valley deposits. Except quite near the former ice edge, where the true glacial plain is demonstrably connected with a distinctive head at the ice edge, this discrimination is practically impossible. In many cases the terraces themselves bear characters that awaken the suspicion that they do not represent the true glacial plain. In many cases they do not stand at consistent heights, and in many others they bear a suspicious configuration.

In the immediate vicinity of the ice edge from which the gravel trains originated, it is possible to identify with confidence the original glacio-fluvial plain, if due circumspection is exercised, but I think that it is only within a few miles of the parent ice border and in a few special cases of other types that the conditions are favorable for a trustworthy reference of buried relics, to the ice age.

Adjustment plains as sources of deception.—The chief source of misplaced confidence by even glacialists of ability and experience lies in mistaking a *post-glacial adjustment plain* for a *true glacio-fluvial plain.* It is a familiar observation that the true glacial flood plain rises rapidly as its head at the ice edge is approached. There is for this the obvious reason that the waters issuing from the ice edge are usually heavily overloaded with detritus, and on this account they build the stream bottoms up to a high gradient. When the ice retires and the waters become purer a readjustment of the gradient follows. This is accomplished usually by cutting down the high gradient at the head and redepositing the material so removed at some point of lower gradient below. Later this adjustment becomes the subject of a new adjustment by which the gradient is again lowered in the upper part, and the material removed in so doing is redeposited still farther down the valley, and so on by a progressive series of partial readjustments until the whole gradient of the valley has been brought into working harmony. The earlier readjustment plains may often be seen a few miles below the terminal moraines on which the true glacio-fluvial plains take their origin. At such points the valley is often filled from bluff to bluff by a smooth plain of gravel of glacial aspect, and the impression is apt to grow into great strength that this is the true glacial flood plain. But as it is traced up toward the moraine, terraces of higher altitudes and higher gradients are seen to rise on the sides of the valley, and grow in strength and continuity until they clearly disclose the earlier plain of which they are the remnants, and this plain is found to merge into the moraine, while the other plain of lower gradient is found to connect with a channel cut through the moraine. In such a declared case, it is clearly seen that the plain of lower gradient (and lower position at the moraine) is the higher plain a few miles down the valley, and is there altogether likely to be taken for the plain of true glacial date. Still farther down the valley a yet later adjustment plain may be uppermost and prevailing, and so liable to be misinterpreted. Errors of interpretation of this kind are liable to be made within five miles of the moraines on which the gravel trains head.

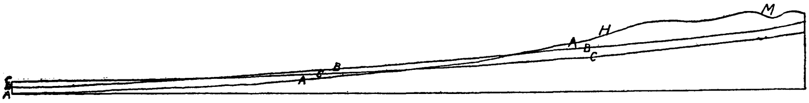

FIG. I.—Illustration of the successive formation of a true glacio-fluvial and two adjustment plains. *M*, moraine at which the true glacio-fluvial plain heads; *H*, head of the valley train of true glacio-fluvial gravel: *AAA* down-stream portions of the same; *BBB*, first adjustment plain, lower than glacio-fluvial plain at the right, and higher at the left; *CCC*, second adjustment plain crossing the horizons of both the preceding. The portions of the adjustment plains at the left are liable to be mistaken for the true glacio-fluvial plain.

Amount of the errors.—At such a distance probably the amount of error in time may not be great, but we really do not know how fast or how slow such a readjustment takes place. While geologically rather rapid, it may be rather slow in terms of human migration. In the nature of the case, the farther the locality is down the valley from the head of the gravel train, the later is the readjustment.

It will be seen from this that even where the valley train of modified drift is well preserved and is clearly the highest plain of the kind in the valley at that point, it may be an error to refer it to strict contemporaneity with the ice presence. For aught that we know, it may have been formed several hundred, and perhaps a few thousand, years after the ice retired. The difference is trivial in geologic terms, but it may be of much moment in human history. No readjustment of this importance, I think, is known to have taken place naturally during the invasion and wide occupancy of this continent by the white race. We should have to draw our geologic lines closer than this to fix the not unimportant period of our people by geologic data.

Without going farther into the refinements of the case it appears—

1. That even where the valley train is well preserved and constitutes a broad plain or extensive terrace, and is the highest deposit of the kind in the valley at that point, and its material is indistinguishable in kind and structure from true glacio-fluvial material, there is danger of appreciable error in referring it to the ice age. In the case of relics imbedded in it there are the added dangers already referred to, unless some special evidence excludes them.

2. That where nothing but isolated terraces are involved much doubt as to the correlation of these is liable to arise legitimately.

3. That where the terraces are below the maximum height for the locality, there is definite ground for suspicion.

4. That in all cases where there is any chance that the river in its degradational stages has meandered over the locality, the possibility of scour-and-fill gives grounds for serious suspicion. The possibilities of natural deep intrusion by this prevailing process are only limited by scores of feet; indeed, only by a hundred feet, or more.

The general purport of these combined sources of possible error is to emphasize *the very unpromising character of valley grav-*

els as a source of really good evidence of man's glacial age. It is clear that these gravels are liable to present many misleading cases, and this is a reason for special caution on the part of geologists, while it is a sufficient ground for anthropologists to withhold the acceptance of supposed evidence of this class until it shall be conceded to be demonstrative by the most critical glacialists.

IV. FLOOD-PLAIN DEPOSITS.

The preceding discussion relates to clear, well-stratified gravel, sand, and silt deposits of the same composition as the true glacio-fluvial formations and of the same general aspect and part of the same complex train of assorted drift deposits. Over these deposits of glacio-fluvial aspect there is usually spread a layer of more or less structureless silt, with intermixed sand and gravel, in which human relics are not infrequently found. There is scarcely a presumption that these surface deposits are of glacial age. They are generally the products of the river floods formed during the stages when the river is sinking its channel into the underlying gravel plain, a stage which is usually reached some time after the glacial floods ceased their work of aggradation. Usually it is not until after the work of adjustment following the close of the glacial stage has been completed, and probably in some cases only after a period of aggradation, due to the special erosion of the drift succeeding the retreat of the ice, has passed.

All flood-plain surfaces of this class should be excluded from ground likely to give any good evidence of contemporaneity with the ice age.

V. BLUFF-BORDER ACCUMULATIONS.

There is a class of deposits closely correlated with river bluffs that have played a part in the discussion of man's antiquity in America. In these cases the bluffs have been cut from plains of glacial or glacial-like gravels, and the deposits on the borders of the bluffs have on this account been referred to a glacial age. There are at least two classes of these. The first is a form of the preceding flood-plain surfacing. As is well known, where a river overflows its bordering bluffs and banks, its largest, and in general its coarsest, deposits are likely to be made on their borders where a low ridge or natural levee is built up. This takes place while the stream is still overflowing its bluffs at high stages. But these may remain on the bluff border after the stream has cut its valley so deep as to cease this overflow. This, of course, depends upon the chance whether the river encroaches upon its bluffs at the given place or not. Such deposits and their contents are to be referred normally to an advanced stage of degradation of the river, and hence presumably some considerable time after the glacial aggradation of the valley and the sequent adjustments had ceased. The strong presumption is against the reference of these deposits or their contents to a glacial age.

The second class are formed by wind action conditioned by the bluff itself, and hence are subsequent to the formation of the *bluff.* The sloping face of the bluff directs upward the wind that blows against it from the valley, and this upward current lifts the horizontal current at the level of the top of the bluff and causes an eddy of relatively quiet air just back of the bluff edge, in which sand, and such pebbles as the intensified wind at the bluff edge may be able to roll back, to lodge and form a low flat ridge. Mr. Knapp has observed many of these in New Jersey and assigned to them their true cause, as it would seem. Their relationship to the bluff edge and to the strong winds leaves no serious ground to doubt their origin. As these are later than the bluff and the bluff is later than the gravels in which it is cut, and as these gravels may even be later than the close of the ice invasion, there is no ground for referring relics found in such deposits to the ice age.

VI. DERIVATIVE FORMATIONS.

These have been touched upon at several points already, but as they are the special danger-ground of the unwary and are liable to deceive the very elect, some further special notice seems required.

Inverted deposits.— The reversal of the order of deposition in the *process of bluff formation* is a special instance. A river that has depressed its channel deeply into a plain of glacial or glacial-like gravels develops its bluffs on either hand, and from time to time forces them back by under-cutting at its aggressive bends. This action for the time is likely to develop nearly vertical bluffs; at least steep bluffs. While the cutting is in progress, the top of the bluff falls into the river and its surface material, with whatever human relics may lie on it, is liable to be strewn along the stream bed under the bluff and beyond. When the stream shifts its course and the cutting ceases, the top still continues to fall or slide or be washed to the bottom. In this way the upper part of the bluff recedes, while the lower part is built forward until a slope of stability is reached. In the process some of the surface material is quite certain to become deeply buried if the bluff be high. This has been amply pointed out and illustrated by Holmes.[1]

As already remarked in other connections, deposits are subject to slumps, creep, and other displacements that introduce chances of error that must be carefully eliminated.

So also loess bluffs are notably subject to creep in successive large masses, which preserve their internal integrity, and hence are liable to be regarded as undisturbed. This process is grandly displayed at Vicksburg, where the displacements range through some 200 feet.

VII. RECOMPOSED SECONDARIES.

Misleading as the inverted drifts may be, they are less illusory than some recomposed secondaries. The leading class here consists of *subærial aggradation accumulations.* Nearly every valley is subject to oscillations in the relative activity of erosion and of transportation within its own limits Sometimes the derivation of material in one part of the valley exceeds transportation in another part, and deposition is the result. The consequence is wash in one part and lodgment in another. These oscillations may be due to changes in the precipitation, in the vegetal clothing, in the relative stages of erosion, in the relations to other streams and to other causes. In these cases the material is derived mainly from the steeper slopes or steeper ravines, and is chiefly deposited on the lower slopes or in the flatter portions of the valley. The secondary deposit is therefore chiefly a low slope deposit and a valley-bottom deposit. It therefore conforms to the natural configurations of the valley; indeed, the new deposit is the very element that gives to the valley its proper configuration under the new conditions. It therefore blends quite perfectly into the common configuration of the new and old surface formations, and the distinction between the new and the old thus blended in configuration is pre-eminently calculated to escape observation.

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[1] HOLMES, JOURNAL OF GEOLOGY, Vol. I, No. 1, 1893.

The formation does not arise from simple displacement or reworking of any one deposit, but is a *recomposition* of material derived from everything exposed to wash in the portion of the valley undergoing erosion at the time. It may be in itself a consistent formation with definite characters and quite free from signs of post-depositional disturbance. As its material was derived from that which prevails on the upper slope of the same valley, it is very liable to resemble it more or less closely, and this, taken with the harmonious topographic configuration, adds to its liability to be confounded with the original deposit. For example, in a valley whose upper slopes are mantled with loess, with few exposures of older formations, the slope wash is necessarily loess-silt in the main, and the recomposed formation on the lower slope or in the valley must be made up of similar silt merely modified by exposure and transportation. The older formations can only make such contributions to the new deposit as their exposure and erosibility permit, which in the case supposed—a common case—is small. The new aggregation must necessarily bear a close *general* resemblance to the original loess and may easily be mistaken for it.

The criteria for discrimination are found in the effects of partial weathering, in the element contributed by the older formations, and in the structure of the new aggregation, besides the special features which most individual deposits possess as their personal characteristics, so to speak. In a valley whose upper slopes are till or other form of drift, similar recomposition formations of an illusive nature take place.

It should be noted in passing that these are not true alluvial deposits in the typical cases, though they may grade into alluvial deposits and be interstratified with them. They are not habitually well assorted and stratified. They are not formed by persistent streams, but are the products of periodic surface wash and are heterogeneous, unassorted, and, in a sense, structureless, and hence again their liability to be mistaken for one or another of the unassorted drifts.

Among the favoring conditions for such recomposition deposits, there is one which is systematic and recurrent, and is peculiarly adapted to occasion the burial of relics, since it causes a succession of alternate erosions and depositions at localities specially liable to be frequented by primitive man. It is the effect of the meandering of a principal river on erosion and deposition in the mouths of its tributaries.

The meandering of a principal river as a cause of alternate erosion and deposition in the mouths of its tributary valleys. — A meandering river with a deep, readily shifted bottom-filling of the glacial type imposes upon its tributary valleys alternate stages of excavation and filling. These result (1) from the action of the aggressive bends of the river loops against the mouths of the tributaries, and (2) the replacement of these, after a time, by the flood-plain peninsulas that lie within the loops. More specifically, it is the alternate cutting of the stream itself, working hard against and under the mouth of the tributary valley, followed by the building up of the river's higher flood-plain across the mouth of the valley. The first causes the waters of the adjusted tributary to erode; the second, to make deposits in the mouth of the tributary; for in the first stage the axis of the tributary opens out on the river itself, which may be twenty or thirty feet or more lower than the upper flood-plain, and hence the tributary then has its lowest and best opportunity to discharge its waters and their detrital burden. Besides this, the river itself, while in this aggressive attitude, sweeps into the mouth of the tributary in its flood stages and aids in its excavation, and the rushing by of the river's strong current drags out by friction, on the principle of draft, the waters of the tributary and, by acceleration, aids their excavating action. It is at this stage pre-eminently that the tributaries cut down their valleys into adjustment with the main stream bed. On the other hand, when the active impinging bend of the river has shifted elsewhere, and in its stead a flood-plain is being built up across the mouth of the tributary, the drainage of the latter is checked, and if the tributary be small and its waters incompetent in comparison with the flood-plain aggradation of the river, the valley mouth will be filled to a height corresponding to that of the highest flood-plain.

Further, if the mouth of the tributary be blocked by the upper flood-plain beyond the time of the latter's growth, the wash from the tributary will build a delta or fan upon it, and this further growth will continue until the waters from the tributary valley have built up a suitable gradient for themselves across the flood-plain to the river. This only holds good in valleys of incompetent drainage which cannot cut and maintain a trench for themselves. If the tributary valley has a large competent stream, it will maintain a channel-way across the flood-plain to the river, and less aggradation will result from the shifting of the meanders.

A series of aggradation deposits of the recomposition type are to be looked for on the lower slopes and in the mouths of all tributary valleys, caused by the shifting action of the primary stream, and these may reach depths of twenty or thirty feet, and theoretically much more. As these deposits are subject to geologically rapid construction and removal, they are peculiarly well adapted to bury whatever may occupy the surface in the erosion stage. But such burial must be referred to the date of the recomposition and aggregation of the material, and not to that of the chief parent formation.

Beside this systematic, constantly recurrent case there may be others assignable to the causes named and to more special agencies.

Palæontological criteria.—The previous discussion has been confined to formations within the glaciated area, or immediately connected therewith. Formations not physically connected with the glacial deposits cannot usually be correlated with the glacial stages so definitely by stratigraphic or other physical means as to furnish unquestionable evidence of their glacial age. In special cases it may be possible, but these cannot well be treated here. The question is, however, pertinent whether palæontological evidence cannot bring these outlying non-glacial deposits into sure correlation, as it does in other parts of the geological column. It is certainly to be presumed that palæontology can do for the Pleistocene period what it has done for earlier ages, but the real question is whether this meets the minute requirements of the question in hand. Has palæontology at any stage reached a degree of refinement that enables it to discriminate surely between stages of the order of the glacial epochs *by the use of criteria developed in other regions than those immediately concerned?* It will not be questioned that when the faunas and floras of each of the glacial stages in America have been well worked out and demonstrably connected with those stages, and when it is shown by ample evidence that certain species lived in America in certain stages, *and not in others*, the criteria so determined can be used in confident correlation; *but these criteria must first be demonstrated to be true criteria in their American application.* General inferences as to the rate of evolution or the rate of extinction are not sufficiently refined for the purposes of this case, without such specific local demonstration. General inferences and faunal aspects may be applicable to periods measured by hundreds of thousands or millions of years, and yet be quite too broad to discriminate epochs of a few thousands or even tens of thousands of years. The historical period of eight or ten thousand years gives little basis for confidence in palæontological refinements of this latter order; certainly not until their specific trustworthiness in a given application is demonstrated. Here as everywhere else in the geological column the range and limitation of species must be demonstrated stratigraphically before the occurrence of these species can be used to fix horizons and determine correlations except in a general and tentative way. The palæontology of the American glacial series is yet to be developed in the main. It is known that many species survived the earlier and more extensive ice invasions, and became extinct either during the later stages or since the glacial period. It is known that some species survived for some appreciable time after the last glacial stage, and yet became extinct before the American historical period, as, notably, the mammoth and mastodon. The fauna of which the mammoth and mastodon were the elephantine types not unlikely bore an aspect measurably different from that of the same region today, and, but for the stratigraphic proof to the contrary, would undoubtedly be regarded as evidence of rather high antiquity, as indeed was the actual case before the recency of this fauna was demonstrated. The association of man's relics with those of extinct animals merely raises the Janus-faced question whether it means the antiquity of man or the recency of extinction of the animals. General considerations and Old World analogies are incompetent to decide this question in America. It must be worked out by specific stratigraphic and correlated evidences of a degree of precision and refinement commensurate with the geologic minuteness of distinctions involved in the problem.

CONCLUSIONS.

The foregoing analysis has not been carried into all the refinements that special cases involve, but it has perhaps been extended far enough to make clear the general fact that the reliable reference of human relics to a glacial age is attended by many possibilities of error, and that these can be avoided only by the exercise of sagacity, guided by experience and controlled by the most diligent circumspection.

Promising grounds.—Two general classes of formations furnish promising grounds for search, so far as their *trustworthiness* is concerned, when critically studied, viz.: (1) the immediate glacial formations, *i. e.*, the till sheets and the moraines; and (2) the interglacial formations.

Unpromising grounds.—Certain other classes of formations are so subject to error, or at least to the suspicion of error, that there is very slight ground of hope that they will furnish incontestible evidence, and hence cases founded on these formations should be relegated to the category of doubt, unless the special features of the cases themselves give them convincing force. These classes are: (1) the valley trains of gravel, sand, and silt, except where immediately connected with moraines or possessed of special features that demonstrate their strict contemporaneity with an ice invasion; and (2) all secondary or disturbed deposits, and all recomposition deposits.

All deposits connected genetically with river channels, with eroded bottoms or bluffs formed in valley trains of gravel, are *to be entirely excluded from serious consideration.* They not only do not help on the cause of glacial man in America—if one may speak as an advocate—but they hinder it by throwing doubt over the whole evidence with which they are associated.

The important question of man's antiquity in America will, in my judgment, be helped on to solution most effectually by freely relegating to the shelves all doubtful evidence and by turning search toward the sources whence reliable evidence is most likely to be forthcoming, and by giving to that search the highest possible credentials of scientific trustworthiness. A few really good cases standing by themselves in their own good company would be decisive; a thousand weak ones can only leave the question in doubt.

T. C. CHAMBERLIN.